ON THE ESTABLISHMENT OF A STANDARD MERIDIAN LINE FOR SANTA CLARA COUNTY, CALIFORNIA.

By James E. Keeler.

A few months ago, at the suggestion of Professor Holden, Mr. Chas. Herrmann, County Surveyor of Santa Clara county, and Mr. A. T. Herrmann, Surveyor and Civil Engineer, obtained the permission of the County Supervisors to establish a standard meridian line in San José, for the benefit of surveyors, with a sufficient sum of money to provide suitable monuments.

It was agreed that the astronomical staff of the Observatory should make the necessary observations without expense to the county, and I was appointed to carry out the work.

Absolute directions on the earth can only be determined by reference to the heavenly bodies. The magnetic needle has been and still is extensively used as a secondary means of determining directions, but the angle which the magnetic needle makes with the true meridian is constantly changing, and is, moreover, subject to sudden and irregular variations, so that, even with the greatest precautions, the compass is an unsafe guide. Ignorance of these facts, or of the amount of necessary allowance from lack of a suitable standard of reference, has given rise to an endless amount of litigation in this country. It is safe to say, that if each county in the Union had legally established a standard meridian in the early days of its settlement, the gain to the country would have to be estimated by hundreds of thousands of dollars.

The remedy for the evils resulting from the secular change of the magnetic declination has been repeatedly pointed out, ever since the days of Rittenhouse. Prof. Gillespie, in his well-known work on Land Surveying, says (p. 210): "The only complete remedy for the disputes, and the uncertainty of bounds, resulting from the continued change in the variation, is this: Let a meridian, *i. e.*, a true north and south line, be established in every town or county, by the authority of the State; monuments, such as stones set deep in the ground, being placed at each end of it. Let every surveyor be obliged by law to test his compass by this line, at least once in each year. . . . . Let the variation thus ascertained be inserted in the notes of the survey and recorded in the deed. Another surveyor, years or centuries afterward, could test his compass by taking the

bearing of the same monuments, and the difference between this and the former bearing would be the change of variation. He could thus determine, with entire certainty, the proper allowance to be made in order to retrace the original line, no matter how much, or how irregularly, the variation may have changed, or how badly adjusted was the compass of the original survey."

But although these evils have been thus forcibly stated, even in the text-books of every school, and the remedy so clearly pointed out, very little interest has been taken in the matter by State authorities. Professor HOLDEN, while Director of the Washburn Observatory, once proposed to establish a standard meridian in every county-seat in the State of Wisconsin, for the bare personal and traveling expenses of an observer, an offer which was declined without thanks.

There is no doubt that the Lick Observatory would assist in such a plan for California, by every means in its power, should the proper authorities be willing to pay the bare expense of the undertaking.

It may be noted that the value of a standard line of reference is particularly great in a newly settled country, where the compass is more relied upon than it is in older communities with well-established boundaries and landmarks.

The scene of our operations in San José was what is known as the "Meridian Road," because it is supposed to be in the line of the Mt. Diablo meridian. It has been the practice of surveyors to test their instruments by sighting up and down this road, which, however, contains no marks sufficiently definite to admit of a precise determination by this method. The north end of the road terminates at a high board fence which forms the southern boundary of the Fair Ground, and on a shelf secured to this fence a mark was put up, consisting of a hole one-half inch in diameter in a thin plate, illuminated from behind by a bull's-eye lantern. Two thousand feet south of the mark a substantial pier of brick and cement was built for the support of the instrument. The mark was as nearly in the meridian of the pier as could be determined with the aid of a compass. At the pier it subtended an angle of 4″, and to the naked eye appeared as a star of about the first magnitude.

The instrument employed was the REPSOLD altazimuth briefly described in Vol. I, Publications of the Lick Observatory, and more completely in my report on the geographical position of Norman, California, in the Reports on Observations of the Total Eclipse of January 1, 1889, published by the Lick Observatory. It has vertical and horizontal circles ten inches in diameter, read to 2″ by microme-

ter microscopes, or by estimation to 0″.2. All necessary attachments are provided for exact astronomical work. The time-piece used was a sidereal chronometer, Negus 1720.

Preliminary observations were made on the night of August 5th, and more accurate ones on August 6th and 7th. The azimuth of the mark was determined by alternate readings on the mark and on *Polaris* near eastern elongation, the instrument being reversed during the measurements to eliminate the error of collimation. The latitude of the pier was determined, with sufficient accuracy, by measuring the zenith distances of four stars with the vertical circle, and the local sidereal time by using the altazimuth as a transit instrument. No elaborate time observations were made, as a knowledge of the time to within one second is amply sufficient for computing the small reductions to elongation. The horizontal circle was turned one-third round on August 7th, in order to bring different divisions under the microscopes.

Ten observations of the mark and ten of *Polaris*, on August 6th, made the mark 1° 22′ 48″.0 west of the vertical circle passing through the point of elongation. The computed azimuth of the star corrected for diurnal aberration, was 1° 37′ 7″.2, hence the azimuth of the mark was + 0° 14′ 19″.2.

From six observations of the star and six of the mark, on August 7th, the mark was west of the star 1° 22′ 50″.6. The computed azimuth of the star was 1° 37′ 6″.8, and hence the azimuth of the mark was + 0° 14′ 16″.2. The adopted azimuth of the mark was 14′ 17″.7 east, which, at a distance of 2000 feet, corresponds to 8 feet 3.8 inches, and the mark was moved this distance to the west to bring it into the meridian of the centre mark on the pier. The estimated probable error of the meridian is 2″, or about one-quarter of an inch at a distance of 2000 feet, a quantity thirty times smaller than the smallest angle which is measured with ordinary surveying instruments. From the above data permanent monuments will be established by the Messrs. HERRMANN.

For the convenience of those who cannot avail themselves of this meridian line, I have computed the following table of azimuths and times of elongation of *Polaris* for the latitude and longitude of San José. The azimuths are given to the nearest 10″; the times of elongation in *Standard Pacific Time* to the nearest minute. For San Francisco the azimuths must be increased by 40″, and the times of elongation will be about two minutes later. An error of thirteen minutes in the time of elongation will produce an error of only 10″ in the azimuth. The formulæ from which this table was com-

puted may be found in DOOLITTLE'S Practical Astronomy (p. 527).

If the meridian is determined from observations of *Polaris* near elongation by a surveyor's transit, the line of collimation must be adjusted with especial care, so as to travel on a truly vertical line. As there are several minutes near elongation during which the azimuth of the star does not differ appreciably from the tabulated value, it is better to make two observations of the star, one with reversed position of the telescope, and take the mean of the readings of the horizontal circle. It must be remembered that the reading of the compass needle, when the sight line of the instrument is in the meridian, is not necessarily the magnetic declination, since the line of zeros of the compass circle may not be in the same plane with the line of collimation (as, of course, it should be). The reading of the needle will, however, be the declination *for that particular instrument*, and true bearings can be taken just as well as if the adjustment were perfect.

TABLE OF AZIMUTHS AND TIMES OF ELONGATION OF *POLARIS*.

(Computed for the latitude and longitude of San José, Cal., by J. E. KEELER.)

DATE.	W. ELONGATION.	E. ELONGATION.	AZIMUTH.
	h. *m.*	*h.* *m.*	° ′ ″
1889. Sept. 6....	8 19 A.M.	8 25 P.M.	1 37 00
" 16....	7 39 "	7 46 "	1 36 50
" 26....	7 00 "	7 06 "	1 36 50
Oct. 6....	6 21 "	6 27 "	1 36 40
" 16....	5 42 "	5 48 "	1 36 40
" 26....	5 03 "	5 08 "	1 36 30
Nov. 5....	4 23 "	4 29 "	1 36 30
" 15....	3 44 "	3 50 "	1 36 20
" 25....	3 05 "	3 11 "	1 36 20
Dec. 5....	2 25 "	2 31 "	1 36 20
" 15....	1 46 "	1 52 "	1 36 10
" 25....	1 06 "	1 12 "	1 36 10
1890. Jan. 4....	12 27 "	12 33 "	1 36 10
" 14....	11 43 P.M.	11 53 A.M.	1 36 10
" 24....	11 04 "	11 14 "	1 36 10
Feb. 3....	10 24 "	10 34 "	1 36 10
" 13....	9 45 "	9 55 "	1 36 10
" 23....	9 06 "	9 16 "	1 36 10

Date.	W. Elongation.			E. Elongation.			Azimuth.		
	h.	*m.*		*h.*	*m.*		°	′	″
1890. Mar. 5....	8	26	P.M.	8	36	A.M.	1	36	20
" 15....	7	47	"	7	57	"	1	36	20
" 25....	7	07	"	7	17	"	1	36	20
April 4....	6	28	"	6	38	"	1	36	30
" 14....	5	48	"	5	58	"	1	36	30
" 24....	5	09	"	5	19	"	1	36	40
May 4....	4	30	"	4	40	"	1	36	40
" 14....	3	50	"	4	00	"	1	36	40
" 24....	3	11	"	3	21	"	1	36	50
June 3....	2	32	"	2	42	"	1	36	50
" 13....	1	53	"	2	03	"	1	36	50
" 23....	1	14	"	1	23	"	1	36	50
July 3....	12	35	"	12	44	"	1	36	50
" 13....	11	55	A.M.	12	04	"	1	36	50
" 23....	11	16	"	11	22	P.M.	1	36	50
Aug. 2....	10	37	"	10	43	"	1	36	40
" 12....	9	58	"	10	04	"	1	36	40
" 22....	9	19	"	9	25	"	1	36	40
Sept. 1....	8	40	"	8	46	"	1	36	30
" 11....	8	00	"	8	06	"	1	36	30
" 21....	7	21	"	7	27	"	1	36	30
Oct. 1 ...	6	42	"	6	48	"	1	36	20
" 11....	6	02	"	6	08	"	1	36	20
" 21....	5	23	"	5	29	"	1	36	10
" 31....	4	44	"	4	50	"	1	36	00
Nov. 10....	4	05	"	4	10	"	1	36	00
" 20....	3	25	"	3	31	"	1	36	00
" 30....	2	46	"	2	52	"	1	35	50
Dec. 10....	2	07	"	2	12	"	1	35	50
" 20....	1	27	"	1	33	"	1	35	50
" 30....	12	48	"	12	54	"	1	35	50
1891. Jan. 9....	12	09	"	12	14	"	1	35	40